SUMMARY of POLARIZER WORK, 1/10/05

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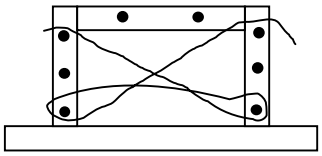
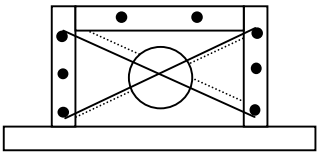
Cell choice: We decided to continue with BooBoo, rather than changing to Pebbles, for the following reasons: a) Although Pebbles has a much more uniform 3He thickness, the useful diameter of Pebbles is just under 10 cm. Hence we would probably want to use a smaller collimator, which would offset gain in polarization. b) The average thickness of BooBoo is 4.9 bar-cm, while Pebbles' thickness is only 4.3 bar-cm. Recent evaluations of the optimum thickness (based on the now known spectrum) indicate that thicker is better. c) We wanted a point of reference, ie. the polarization value already obtained in BooBoo, so as to evaluate possible improvements. d) If we add a third laser, the difference in achievable polarization for BooBoo as compared to Pebbles (55% for BooBoo vs. 60% for Pebbles at NIST) may decrease. e) If it ain't broke, don't fix it; we may need Pebbles (or other cells) if BooBoo dies. However, we note that there may be some evidence for oxidation in BooBoo. A little oxidation, in and of itself, is not detrimental, but if it indicates that BooBoo has a slow leak, it will have to be replaced. BooBoo will be pumped to saturation in the next few weeks; if a decline in polarization is seen once the saturated polarization is reached, we should consider the leaking possibility. Note that if the cell is leaking, the polarization determined from neutron transmission data will increase (assuming a fixed value of T0 is used) because the neutron transmission will increase. In contrast, the NMR signal will decrease if the cell is leaking.

Oven and cell alignment: We aligned the oven to the beam using the theodolite and crosshairs on the oven. The crosshairs were strung around the corner screws of the front and back of the oven. (A diagram and more info can be found on pg. 14 of the notebook.) The center of the crosshairs was centered north-south in the oven, ie. 5.0" from each side of the 10.0" wide oven. Vertically, the center of the crosshairs was 5.0" from the bottom of the oven. Locking nuts were installed on the oven support screws. The vertical movements of the oven for this realignment were less than a few mm, but the whole oven was moved about 4mm north. The north (south) side of the blue oven box (outside at the bottom) is now 18.25" (18.12") from the inside of the north (south) side of the static field coils, and the bottom of the blue oven box is 46.75" from the floor.



Once the oven was aligned and the oven stops were tightened, we slid the oven north and aligned the cell to the oven. We marked dots at the center of BooBoo, using our judgement as to what portion of BooBoo's area should be used (+- 4mm?). The more accurate mark was made on the upstream side which has a "ridge" around the outside of the cell. From the upstream side, we sighted through the crosshairs and moved BooBoo until the upstream dot was at the center of the crosshairs. Although one cannot see the center of the downstream crosshairs due to lensing by the cell, one can still sight such the crosshairs are overlapped in the region beyond the cell radius. We estimate that our defined center of BooBoo is within a few mm of the beam center. Although the precision of this alignment is not such an issue for BooBoo (it is big), care will be required if a smaller cell like Pebbles is installed.



FID NMR polarization monitor: It is not completely clear what was causing the noise seen on the FID signal in the last run, but it is currently gone. Tim blanked the preamp instead of shorting the preamp with a relay which seems to have increased the stability of the signal. The FID signal currently has excellent stability and signal to noise; the noise level corresponds to few tenths of a percent of polarization. The loss per tip is less than 0.1%. (0.05V, 2ms pulse into a 0.7mH coil around the pulloff, coil resonance around 65 kHz.) There is evidence for radiation damping effects in the FID signal. In the absence of radiation damping, the decay time constant is given by T2, the transverse relaxation time, and is related to the range of magnetic fields present in the cell. If the 3He is in the lower (upper) energy state, radiation damping leads to a shortened (lengthened) decay of the FID signal. The degree of shortening or lengthening is proportional to the magnetization and the effective Q of the pickup coil. Weak radiation damping is not a problem since the initial signal amplitude does not change, but the shape can change the fitted height of the FID signal. Tim removed the radiation damping by removing the coil tuning capacitor bringing the coil resonance to above 60kHz. This far off resonance we loose signal (about a factor of 6) but see no effects from radiation damping.

It may be possible to reproduce this signal for a given cell, if we can reproduce the location and angle of the pickup coil on the tip-off (it will probably go back to the same place if one pushes it on until it stops), the orientation of the tip-off (the location of the tip-off with respect to the screw that nearly touches would be an easy way to do this), and the NMR parameters (tip-off angle, beat frequency). We should attempt to calibrate the FID signal against neutron measurements and document the relevant information so that this calibration can be useful when there are no neutrons. This will give us a ballpark figure for the polarization.

AFP reversal of polarization: The frequency-sweep AFP reversal of the magnetization is now operational and the AFP loss is under 0.1% in a single sweep (flipping the polarization). It was found that it had not been working because the RF amp was being overloaded, leading to distorted RF drive. Reducing the function generator output to 0.9 V p-p solved the problem. Reducing the sweep speed from 20 kHz/s to 5 kHz/s improved the AFP efficiency from 99% to 99.9%. It is possible that it can be improved further, hence the AFP efficiency vs. sweep is being mapped by Mike and Marty. The "sweet spot" appears to be quite large, but if needed, the RF power could probably be increased by changing the number of turns in the RF coils to better match the output impedance of the RF amp.

NMR code: Gordon has simplified both the panel and the code for NMR to make it more user (and hacker) friendly. Start Igor with the most recent procedure file, then type "init()" to pull up two windows. The Control Window (right hand side) contains actions and the Parameter Window contains, oddly enough, NMR parameters. The Control Window is divided into tabs or folders. The initial tab, labeled "NPDG", contains all of the actions that a non-expert might want to perform.

Control Window (right hand side):

NPDG tab

All "non-expert" functions are contained in the "NPDG" tab: single coil FID (measure relative polarization), frequency sweep AFP (flip polarization) and Kill Polarization (using fast AFP). Each NMR action is associated with an an "FID number" or counter. For each sweep, the data (x and y phases) and parameters are both saved, indexed by the FID number. This tab also includes a button to show the recent history of the FID signals to look for trends, a button to bring up a table of information on all of the recent FID, AFP, Kill actions listed by FID number.

MULTIPLE tab

This includes controls for measuring the pump up rate, spin down rate, FID loss, and AFP loss; all functions that require multiple NMR sweeps/pulses. You can also fit old data indexed by FID number.

RF/Lockin tab

Allows remote control and monitoring of the function generator and lockin amplifier.

Utilities tab

Allows you to fit old NMR data, review old NMR parameters, control files, etc. This also lets you control GPIB and NIDAQ digital I/O for debugging purposes.

Parameter Window

FID tab

Lists all parameters for FID pulses. Except for the frequency, these should not change. Once good parameters are found they should be hard wired into the FIDinit() function. The only one likely to change is the frequency parameter which will change with magnetic field. A complete list of current parameters is in the log book, but the most important parameters are: Tpulse = 2 ms, Vpulse = 0.05V. The rest frequency should probably be changed to 1Hz…very far from resonance!

AFP tab

Again, these should not change from the hard wired parameters in AFPFinit(). Voltage = 0.9V, Rate = 5kHz/sec, Range = 20kHz – 50kHz

Kill Polarization tab

I found (see log book) that the AFP loss gets larger as the sweep rate increases above 30 kHz/sec, reaches a maximum loss somewhere around 50 kHz/sec, and then decreasing as the rate becomes too fast to flip the spins above 70 kHz or so. The amount of loss can be changed by varying this sweep rate, but the most loss is probably between 40-60 kHz/sec.

The RF amp can be left on with no loss of polarization. However, you can't accidentally perform a spin flip or kill the 3He polarization if the amp is off. I recommend leaving the amp off most of the time as added protection.

A circuit diagram for the NMR can be found in the logbook, or by sending a self addressed stamped envelope to Mike Dabaghyan. Basically, the output of the function generator is fed into a "slow" relay switch (switching between FID mode and AFP mode) controlled by a digital output from the NIDAQ board. In FID mode, the output of the FID/AFP switch is run through two redundant reed relays. These relays are turned on briefly (by the counter output of the NIDAQ board.) to let an RF pulse through to the pickup coil. The preamp is also connected to the coil, but it is blanked off during the RF pulse to avoid saturation. In AFP mode, the output if the FID/AFP switch is run through a second reed relay (for redundant protection), through series back-to-back diodes (for redundant protection) and then into the RF amp. The amp drives large (18"?) RF coils around the whole cell. Any leakage in AFP mode will affect the whole cell and can cause additional spin relaxation, so the signal is blocked by redundant switches. Leakage in FID mode only affects a small part of the cell and is less of a concern. For additional leakage protection, the function generator is left at a resting frequency (1Hz?) when NMR is not being performed.

Laser tests and optimization:

Laser power: We measured the power of the lasers by putting the output of the fiber into Tim's power meter (Molectron Power Max 500D).

Top laser (ID# 1107546)	27.2 W @ 38.6 A, 16.5 C
Bottom laser (ID# 1107544)	25.0 W @ 37.0 A, 16.5 C
Third laser (1107545)	27.2 W @ 35.0A, 22 C

This is OK, but a little low.

Laser spectra: Using Tim's spectrometer and the light transmitted through the hot cell, we found that the locations of the absorption dips were off. The top and bottom laser were retuned to 14.1 C and 12.0 C, respectively (see log book for serial numbers). These values should be checked if a slow decline in polarization is observed. Tim will provide a spectrometer to reside at LANL. The low power of the bottom laser is perhaps a cause for concern, but the temperatures had probably been changed since spring 2004.

The top laser has a linewidth of about 2.2 nm and a nice symmetric profile. The bottom and third lasers' linewidths are closer to 2.5 nm. The spectrum of the bottom laser is a bit asymmetric and the third laser is the worst of the three. Note that small changes in the operating current can change the shapes. Plots from the spectrum analyzer are in the notebook.

Circular polarization: Using a small polarization cube from the laser lab, we checked the circular polarization of the bottom laser. For each beam, the transmitted and reflected beams from the cube were within about 20% of each other, corresponding to a degree of circular polarization of 99.5%. We didn't check the top laser because it would have been somewhat difficult.

Beam alignment and size: We aligned and sized the beam by observing the light transmitted through the cell. Thanks to Mike D, we found that this can be easily observed by putting a piece of paper in the beam and looking at the paper with the IR viewer. One can also use the IR card, but the viewer was more convenient. Gordon took digital photos of the transmitted beam, both with and without going through the IR viewer which (presumably) Mike has added to the notebook. We first expanded the beam by about 10 turns of the mount for the collimating lens and adjusted the beams, one at a time, so that we observed a clear ring of the light outlining the shadow of the cell. One oval beam illuminates the north side of the cell and the other illuminates the south side, with substantial overlap in the center. After establishing a fairly uniform ring of light, we decreased the size of the beams (by moving the collimating lens further from the fiber) until the ring was barely visible, so that essentially all the light is hitting the cell. The initial pump-up rate was 9% higher for the smaller beams.

This illumination scheme is not the same scheme used at NIST. At NIST each ovals is expanded to illuminate the full long dimension of the cell and a slight difference in alignment allows the full short dimension of the cell to be covered. Given the shorter distance from the polarizing optics to the cell in the npdg setup, the existing scheme may be better for the npdg polarizer.

Initial pump-up rate tests: We did some measurements of the initial pump-up rate, which for a given temperature is proportional to the Rb polarization. Note that the difference between the value of polarization obtained at NIST (55%) and that obtained at LANL in the last run (47%) is only about 17%. In comparing initial pump-up rate measurements, one must keep in mind that a 2 C change in cell temperature will yield a 12% change in initial rate. Since the heater system takes a long time to stabilize and we had some issues with the oven, there may have been 1-2 C differences in actual cell temperature for our measurements that were nominally taken at the same temperature. Before realigning the beams, we compared the rate for the old laser temp values (16.5 C and 16.5 C) to the rate for the new laser temperatures (14.1 C and 12 C); the rate for the new temps was 18% higher, but there were some NMR issues that may make this a slight overestimate. Operating at the new laser temperatures and at an oven temp of 157.5 C, we obtained 8% higher initial rate in our final beam alignment configuration as compared to before we touched the alignment, but the uncertainty is probably also 8%. If we assume that the lasers were properly tuned during the last run, then only the alignment-related improvement in the initial rate is relevant. About all we can say is that the final polarization in BooBoo might be better, and is probably not worse.

Future work:

1) Measure initial pump-up rates for each laser individually.
2) Using the initial pump-up rate, test effect of further reduction in beam size (just doing reversible, documented changes to the collimating lens).
3) Measure full pump-up curve at 160 C to obtain saturated NMR signal and pumping time constant. Since we expect a pumping time constant of about 20 hours, this will take 2-3 days.
4) After reaching the saturated polarization, decrease temp by 5 C to see if the polarization increases. Again, it will take a few days to measure the possible improvement. If the polarization actually decreases (unlikely), try a 5 C increase. If there is an improvement, try another 5 C decrease. For each 5 C, the pump-up time constant will decrease by about 30%, hence longer times will be required to evaluate the result.
5) See if there is any evidence for a slow decrease in polarization.
6) Cool the cell and measure the room temperature relaxation time, which should be about 500 hours if there is no contribution from gradients
7) Consider shifting the pickup coil resonance or reducing the pickup coil Q if radiation damping effects seem too large for the saturated signal.
8) After we have a neutron measurement for BooBoo, consider installing the third laser using the fiber combiner. This will require changes to the beam alignment and sizing because the combiner produces two spots. By rotating the fiber, one can rotate the spots and it is probably best to orient the line between the center of the spots to be parallel to the long dimension of the cell. We will have to adjust the collimating lens and alignment to illuminate the cell correctly. In addition, we have to decide which two lasers to combine; I am inclined to send two lasers from the bottom because I think that light will get into the cell more efficiently from the bottom because of the shape of the cell as well as where the Rb seems to deposit.
9) Optimize AFP efficiency.